Space Weather Technical Forecast

Issued on Monday, 26 December 2022 at 12:45 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Active electron fluence possible at first, attenuating as Minor or possibly Moderate Geomagnetic activity from a series of CMEs and fast wind regimes take effect.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low over the last 24 hours, with X-ray activity at GOES16 confined to occasional low-level C-class activity, with this mostly from AR3169, as in recent days. This group showed some movement in its diffuse trailing region, with slight spreading and decay, ending the period as a Fsi/Beta-Gamma. One of the largest flares of the period was a long-period C2.9 peaking at 26/0035UTC, perhaps largely from AR3169 but with a possible contribution from a new sunspot developing near the northeastern limb. This latter group eventually presented as a Csi/Beta, having developed significantly over the preceding hours. This group then eventually produced a late peak flare of the 24 hours in the form of a C4.0 at 26/1011UTC.

There were up to seven sunspot regions on the disc in the 24 hours, including the two mentioned above. Of the remainder, the more noteworthy were AR3175 in the southwest which saw some proliferation of spots to finish as a Dro/Beta, while AR3171 showed an east-west magnetic neutral line, but with its southern spots fading as a Cso/Beta. The rest of the Earth-facing side was less notable and either stable or in slow decay.

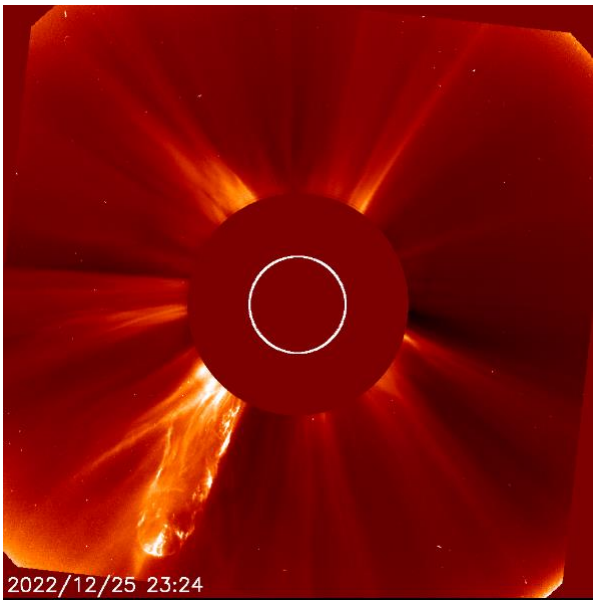

Figure 0: Lasco C2 coronagraph imagery of the 25/2130UTC prominence erution from the southeastern limb. This feature is not expected to affect Earth, being directed both east of and below the Sun-Earth line.

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Two main prominence eruptions were observed from the eastern solar horizon in the period: firstly a northeast limb event at 25/1800UTC from near the arriving sunspot. This may have subsequently been followed by more minor releases from evidence on coronagraph imagery. Secondly, a large and energetic event was seen from the southeast limb at 25/2130UTC. This latter feature was directed well south and east of the Sun-Earth line to no presumed effect at Earth. No new Coronal Mass Ejections (CMEs) were therefore in evidence in the past 24 hours.

Solar Wind / Geomagnetic Activity: Measurement of solar wind speeds, as measured at L1 by ACE was hampered by the effects of low densities at the recording instruments, with the result that detail in solar wind measures has been more erratic and less precise than is typical over the past 24 hours. This being said, the Earth appears to remain mostly influenced by a positive polarity fast wind regime, probably CH56/+ or perhaps segueing into CH57/+. ACE EPAM LEMS is currently showing a sharply rising trend, which may represent an impending CME (perhaps most likely that emitted 24/0230UTC), however this will become clearer in the coming hours.

At L1, there were two main discontinuities observed, firstly at 25/2110UTC and again at 26/0035UTC, which may represent a resurgence from connection to CH57/+, although this is not conclusive. The phi angle was mostly positive over the 24 hours (away from the Sun), but with a deviation to negative after 26/1000UTC.

The solar wind speed appears to have risen from Slightly Elevated to Elevated levels in the period, with an initial slight fall through the 400s of km/s to rise after 0300UTC through the 500s. The solar wind density was especially suspect, although reported as in single figures ppcc throughout. The IMF rose in the period, peaking near 10nT, while the north-south component ranged from +4 to -10nT, spending much of the period anti-aligned with Earth's field.

In spite of the prolonged negative Bz, provisional geomagnetic activity was in the Quiet to Active range - peaking in the 09-12UTC interval at Kp 4+.

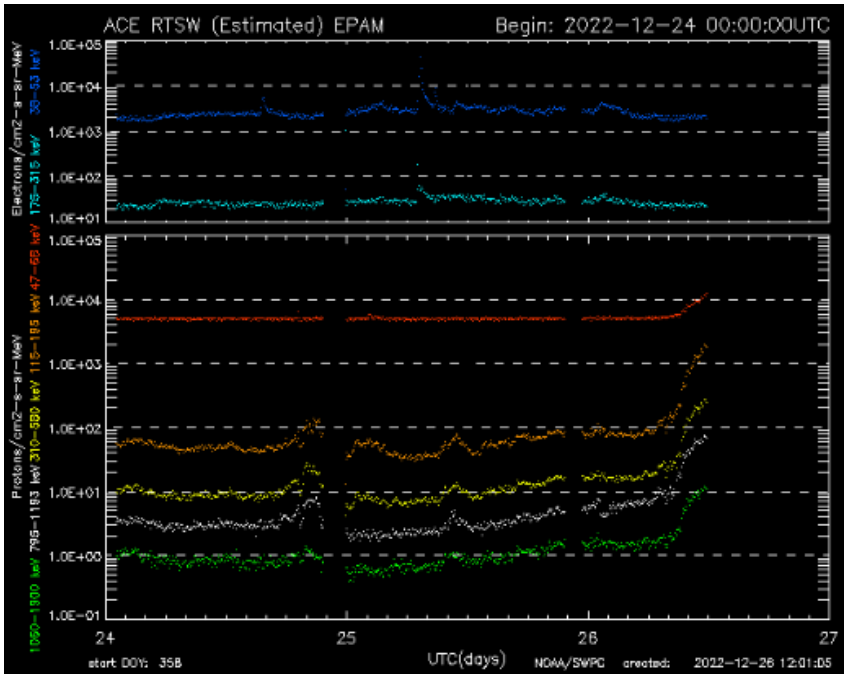

Figure 0b: ACE EPAM LEMS in the past 72 hours showing a marked enhancement that may be a precursor to a CME arrival at L1, perhaps most likely the northeast quadrant filament from 24/0230UTC. This will become clearer into the UTC afternoon.

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Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at Background levels.

High energy electron flux (greater than 2 MeV), as observed by GOES16, varied between Moderate to High flux (1000pfu) levels, peaking at 26/1055UTC at 2950pfu. Electron fluence has been on an increasing trend, with 8.29e7 integrated pfu recorded at 26/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be mainly at Low levels, with a slight chance of M-class X-ray flares, mainly from AR3169, and perhaps now the new northeast limb group.

Solar Wind / Geomagnetic Activity: Three possible CMEs feature in the forecast period, two which left the Sun on 24 December and one from 25 December. Possible arrivals start from late day one, 26 December and into early 27 December, then again on 29 December. The cadence of CMEs over the Christmas period and arising phasing mismatches of these CMEs may make identifying individual events difficult, however.

The fast wind from CH56/+ may still be ongoing early in the period, before the possibly still outstanding arrival of CH57/+. The leading edge of the fast wind from CH59/+ is then possible from late 28 December or more likely early 29 December. With all these holes being positive polarity, identification of movement between them is likely to be difficult.

All considered, geomagnetic activity is forecast to rise over day one to Likely Active or G1/Minor Storm intervals, due to possible CME arrival(s) and a chance of these combining with CH57/+, should the latter be yet to arrive. There is a Slight Chance of G2/Moderate Storm given the potential for a more direct arrival of the 24/0230UTC CME in particular which was marginal for an Earth-directed trajectory but analysed at 1200km/s. Geomagnetic activity should then likely become Quiet to Unsettled 28 December, before a Chance of further G1/Minor Storm intervals on 29 December due to either glancing CME incidence or yet another fast wind arrival from CH59/+.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels throughout, with a daily Slight Chance of reaching S1 levels.

High energy electron flux (greater than 2MeV) may continue at Moderate to High flux levels initially, though CME arrivals from late 26 December onwards could have the effect of redistributing electrons away from GEO. Confidence is therefore low for the possible behaviour of electron flux over the next four days.

Electron fluence values are Likely to breach the Active threshold during 26 December, with the subsequent trend probably downward but with lower confidence and dependence on potential CME arrivals.

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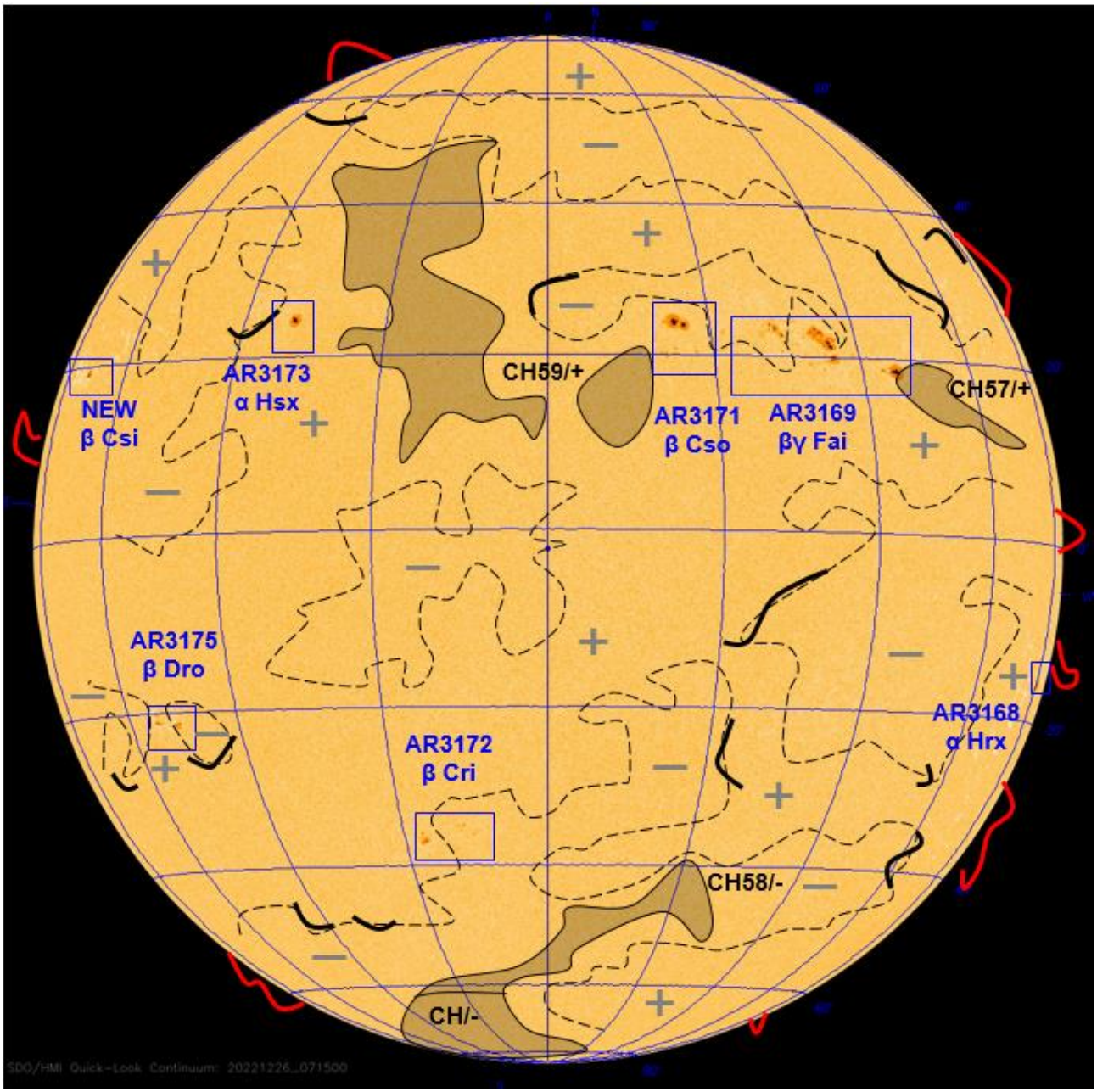
Figure 1. Solar Analysis Valid 26/0715UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are up to three CMEs that feature in the forecast, and up to three fast wind regimes. Note that all the possible incipient coronal holes are of the same (positive) polarity, and the phi angle is not likely to be a useful diagnostic. Also, distinguishing individual CMEs given their weight of numbers on a background of successive fast wind regime resurgences is likely to be very difficult.

Regarding CMEs: the first with a possible Earth-directed component left the northeast quadrant of the Sun early on 24th and may glance the Earth from late on 26th. Main uncertainties with this CME are the angular size of the cone and possible speeds, with a large margin of error across the Enlil ensemble. Given the location of the eruption, in the northeast, slight changes in initial parameters could have a significant impact on whether the feature affects Earth. A further CME which left the Sun from the southwest quadrant later into the morning of the 24th may arrive at Earth on 27th, although this is also low confidence due to limited imagery. The final eruption occurred from the vicinity of AR3168 during a C8 flare early on 25th, this CME seems to be generally missing ahead and below, though it may give very slight impacts at Earth on 29th.

Regarding fast wind regimes: CH56/+ may now have given way to CH57/+, or if not will shortly do so as L1 solar wind data is more erratic than is typical in recent hours for identification purposes. CH59/+ is then perhaps due between the final two days of the period. All of the features due in the period are much-changed relative to last pass, and when considered with the numerous transients mean that the forecast is likely to be both turbulent but also notably low confidence.

Geomagnetic activity is perhaps best described as offering Likely G1 and a Slight Chance of G2 before midweek UTC. From midweek, there remains a Slight Chance of G1, perhaps slightly increasing Thursday as the final CME outstanding perhaps arrives with CH59/+. There are no reliably Quiet space weather windows in the period.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	50	50	20	30
Strong	G3	No	5	5	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
24/0545UTC	Partial	Filament	NE Quadrant	1100km/s	26/1600UTC	Low confidence
24/1415UTC	Partial	Potentially AR3169	NE quadrant	620km/s	27 December	Low confidence
25/1245UTC	Partial	Near AR3168	SW quadrant	525km/s	29 December	Low confidence

Figure 2: Latest 26/0800UTC MOSWOC Enlil run and ensemble showing large variation in possible solar wind density in particular as a result of a train of possible CME glances or arrivals. This serves to illustrate the low confidence in the transient forecast, with differences in coronal hole geometry only exacerbating this as persistence methods are not likely to be useful in any case.

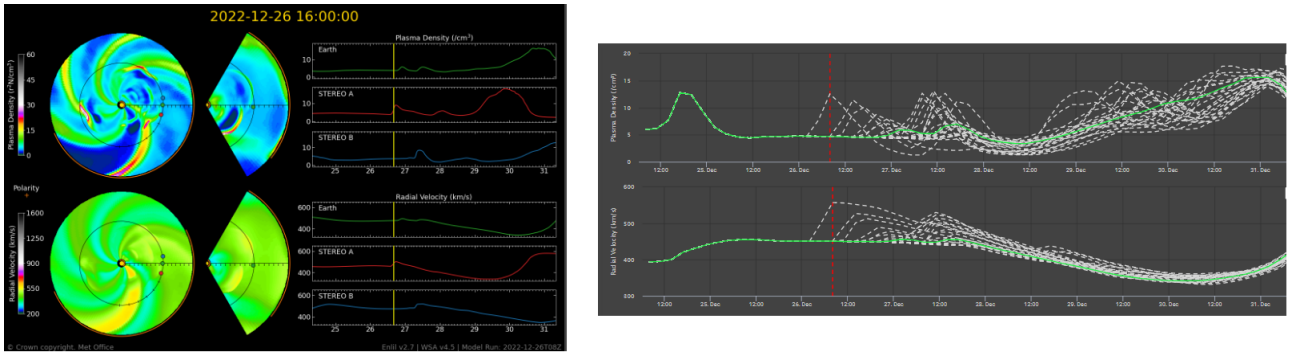
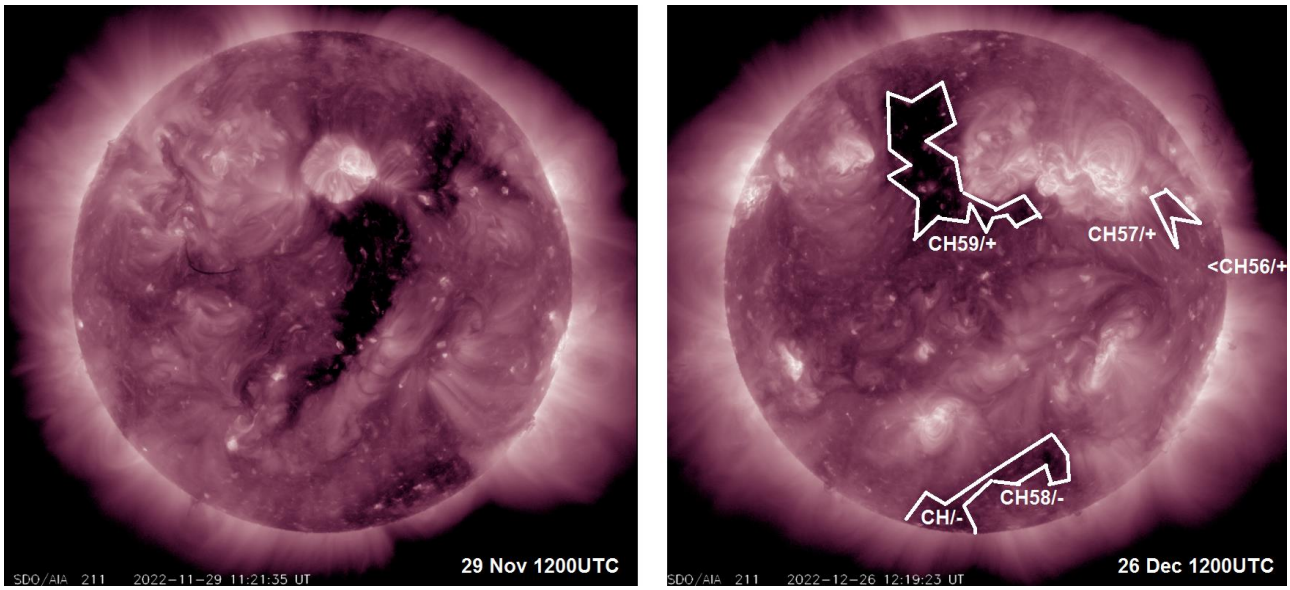


Figure 3: AIA211 imagery from the previous and current rotations illustrating the inutility of persistence in the forecast period.



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Radio Blackouts - X-Ray Flares:

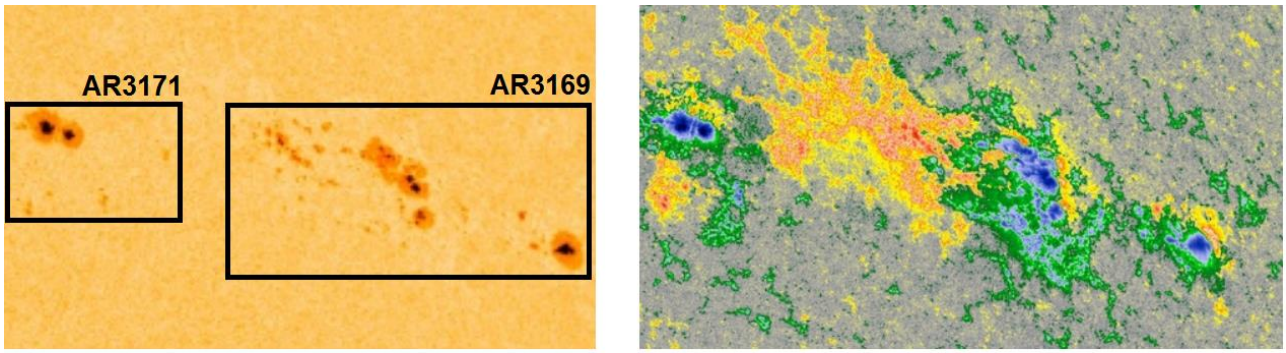
Solar activity has been Low, mostly associated with the large and complex AR3169 in the northwest quadrant through the last 48 hours or so, but also more recently partly attributable to an arriving northeast limb sunspot group. There have been a series of minor CMEs emanating from AR3169 and perhaps signs of possible small delta spot formation, although the latter in particular is tenuous.

Activity has been generally below that expected of similarly complex regions, and X-ray flare risks have been suppressed relative to raw values slightly. There does however remain a Chance of M-class X-ray flares, now slightly bolstered relative to earlier guidance with the arrival of the northeastern spot group.

In terms of the balance of numbers of regions on the front side, AR3169 will be near the western limb by day four as further regions perhaps rotate onto the eastern solar horizon - this based on analysis of far-side soundings. This results in a flat trend, but with tentative signals of a worsening risk in the outlook period (towards the coming UTC weekend) given the possible weight of arrivals.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	25	25	25	25
Very Active	R3 to R5 X Class	No	1	1	1	1

Figure 4: Latest available imagery of complexity in AR3169 and the neighbouring AR3171. The central portion of AR3169 has tenuous candidates for Mt Wilson delta spots, however for now is maintained as a Fsi/Beta-Gamma.



HMIIF and HMIBC at 26/1200UTC

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Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) is expected to remain at Background levels.

Forecast probabilities remain at a Slight Chance due to the possibility of any larger flares from AR3169, although this spot seems to have developed a tendency to discharge its energy regularly and at low levels, with no evidence as yet of any proton enhancements.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) is currently varying between Moderate and High levels. The electron fluence forecast inherits the very low confidence imparted by the geomagnetic activity forecast. The risk of Active electron fluence should be greatest on day one, Monday 26 December, with both confidence and flux falling sharply with any CME arrival, with uncertain recovery given the likely turbulent geomagnetic environment over the remaining days of the period.

Were all the CMEs to miss, flux levels would probably be greatest following the recently observed CH56/+ (perhaps still ongoing), with CH57/+ less threatening. CH59's effects would also probably fall outside the four-day period, with any eventual recovery probably developing before the UTC weekend.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	70	50	20	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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